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Colo., in the last four months, I find a number of specimens of *Ilyocypris bradyi* Sars. A collection made from a small stream in central Illinois in August last, consists entirely of a species of *Ilyocypris*, allied to *I. iners* Kaufmann, which appears to be undescribed.

The genus *Ilyocypris* Brady and Norman is widely distributed in Europe but has not hitherto been found in America. Including the two forms above mentioned, the family Cyprididae is represented in North America by 44 recognizable species comprised in 12 genera. Of these, 2 genera, comprising 3 species, are exclusively American; the remaining 10 genera are represented by 13 species common to Europe and North America, and by 28 species which have been found only in North America.

A full description, with drawings, of the *Ilyocypris* from Illinois is in preparation.

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SPECIAL ARTICLES.

THE DISTRIBUTION OF FRESH-WATER FAUNAS AS AN EVIDENCE OF DRAINAGE MODIFICATIONS.*

As the result of careful studies of stream development, it has been well established by a number of investigators that very important changes in the arrangement of drainage lines are often produced by the capture of a portion of the waters of one stream by a tributary of some neighboring stream. It is but seldom that the actual process of immediate capture is witnessed. We most frequently see the evidence of conditions which we believe will ultimately lead to capture, or results which we believe have been produced by capture sometime in the past.

Whenever one stream succeeds in capturing a portion of the drainage system of one of its neighbors, there are certain results which must necessarily follow, just as there must have been certain conditions present to make the capture possible. By a study of the results produced it is often possible to learn what were the former relations of streams in

a given region, and so prove the fact of capture, and even the approximate time of its occurrence. The evidences of drainage modifications, therefore, are of prime interest to the student of geography.

It is not my purpose to review the several results which are produced when one stream captures another, but rather to direct attention to one of the results produced, and to consider its value as an evidence that capture has occurred. At the outset it is necessary to divide the features produced by river capture into two distinct classes: (1) those features which are produced by river-capture and which can be produced by nothing else; (2) those features which are produced by river-capture, but which may also be produced by some other agency. Features belonging to the first class are of themselves definite proofs that river-capture has taken place. As an example of this type of evidence we may note the occurrence, along the former course of the stream which has suffered capture, of river-brought gravels which are so distributed that they could have reached their present position only through the agency of the captured stream. Features of the second class, however, when taken alone can not be regarded as proofs of river-capture, since, according to the basis of classification, they may also be produced by other agencies. Considered by themselves they are only of suggestive value; other lines of evidence must be appealed to before the river-capture, of which they may be the direct result, can be proved to have taken place. As an example of this type of evidence we may cite the continuation of a broad, open valley along the former course of a large, mature stream which has been diverted by capture. A similar valley may also be produced by a relatively insignificant stream, provided it is working on a band of soft, easily soluble rock, as has been the case along certain headwater branches of the James and Roanoke rivers. The existence of such a valley alone is, therefore, not conclusive evidence of capture, however strongly it may seem to suggest it.

It is well known that different streams are often marked by certain peculiarities of the

* Paper read before the Philadelphia Meeting of the Association of American Geographers.

faunas which inhabit them. The fresh-water shells of one drainage system may be distinctly different from the shells found in the neighboring drainage systems on either side—so much so, in fact, that the student of these forms can often tell at a glance from what locality a given museum specimen has come. Now it is evident that if river-capture takes place, the shells of the captured stream will mingle with those of the capturing stream. Such a commingling of faunas becomes an evidence of drainage modifications, and it is with this type of evidence that the present paper is concerned. It is important to know whether this evidence belongs to the first of the two classes above outlined, being a positive proof of river-capture; or whether it belongs to the second class, and is, therefore, only of suggestive value.

The line of evidence in question is not new. It has already been advanced in support of a great example of supposed river-capture. The Tennessee River after flowing southward through eastern Tennessee to a point near the present city of Chattanooga, leaves its broad, open valley and turns abruptly westward through a deep, narrow gorge in Walden Plateau. Dr. C. W. Hayes and Mr. M. R. Campbell, in a paper on 'The Geomorphology of the Southern Appalachians,' published in 1894, advocated the theory that the Tennessee formerly continued on southward via the Coosa and Alabama rivers into the Gulf of Mexico, but near the close of the Tertiary period was captured at the point near Chattanooga by a branch of a stream farther west. Six years later Mr. Chas. T. Simpson, studying the fresh-water shells of this region, came to the same conclusion; and in a paper on 'The Evidence of the Unionidæ Regarding the Former Courses of the Tennessee and Other Rivers,' published in SCIENCE in 1900, independently supported the theory of capture on the basis of the biological evidence alone.

This latter line of evidence was urged as absolute proof of the supposed river-capture, it being held that the shells must have direct water communication in order to pass from one stream to another. It is true that elsewhere the author has advocated other means

of dispersal than river-capture, but these means were not considered in connection with the Tennessee problem. In this case the whole strength of the argument lay in the statement, 'these forms can not travel overland from river to river, but must have water communication in order to pass from one stream to another.' And since shells peculiarly like those of the Tennessee drainage were found mingled with the usual forms of the Coosa and Alabama rivers the conclusion was reached that the Tennessee must have been diverted from a former southward course by capture near Chattanooga. The paper has been widely accepted and quoted as an example of the definite proof of river-capture, and some who could not accept as conclusive the physiographic evidence presented by Messrs. Hayes and Campbell in support of the theory of capture were impelled to regard the biological evidence a final proof that the capture had taken place.

In connection with a study of the Tennessee problem I have been especially interested in the evidence furnished by the distribution of the fresh-water faunas, and have become convinced that the evidence should be included in the second of the two classes above outlined, being produced by river-capture in some cases, but also being produced by other agencies as well, and, therefore, not being conclusive in favor of capture. The reasons for this will best appear if we consider some concrete case, as that of the Tennessee, in which this line of evidence has been especially employed.

The facts brought forth by a study of the Unionidæ are as follows: *Pleurobema*, a genus of *Unio*, has its metropolis in the Tennessee River. It is not found throughout the other portions of the Mississippi basin. But it is found abundantly in the Coosa and Alabama rivers. Also certain other forms of *Unio* common to the Mississippi-Tennessee basin are found in the Coosa-Alabama basin. From these facts it was concluded that at some time the upper Tennessee River must have flowed southward into the Coosa-Alabama River. On the basis of this line of argument we must necessarily assume that the fresh-water mus-

sels require direct fresh-water communication in order to pass from one stream to another. It appears that the recorded observations of many naturalists and the facts of Unionidæ distribution are both contrary to this conception. In the first place, there are so many authentic cases where birds, insects, etc., have been taken with fresh-water shells attached to them, that students of the subject are compelled to accept this method of dispersion of these forms from place to place. Darwin proved that young molluscs just hatching will attach themselves to the feet of a duck, and remain alive in this position out of water from twelve to twenty hours. Mr. Arthur F. Gray, of Danversport, Massachusetts, had in his possession the foot of a water fowl to which was attached a bivalve shell. Canon Tristran shot a bird in the Sahara which had attached to it the eggs of some mollusc. Some shells attach themselves to plants which are carried away by birds (Darwin). Insects are frequently taken with shells attached. There are at least five recorded cases of the capture of the water-scorpion, *Nepa*, a large flying bug, with small shells attached. The great water-beetle, *Dytiscus*, is known similarly to aid in the dispersion of fresh-water mollusca. The same is true of *Dineutes*. Mr. Albert P. Morse, of Wellesley, has kindly shown me specimens of these last two forms having attached shells. *Notonecta* has likewise been proved to carry these forms from place to place. Some of these insects are powerful fliers. Darwin records the capture of one of them out at sea, forty-five miles from the nearest land. Beddard, Kew and other students of zoogeography regard birds and insects as undoubtedly important agents in the dispersion of fresh-water shells. Woodworth catalogues a number of agencies recorded as aiding in this dispersion, in addition to those mentioned above. It appears, then, that other means besides river-capture for the passing of fresh-water shells from one stream to another are not lacking. That these means are efficient is proved by the distribution of these shells. Ponds are sometimes made by excavating a place where no water stands ordinarily, lining the excavation with concrete

and allowing the rain to fill it. These ponds, for a time devoid of life, gradually become populated with molluscs and other shells, proving, as Beddard says, the capacity for active or passive migration on the part of the Mollusca. Careful and successive observations have proved in some instances the actual time in which a given pond may become populated. R. Ellsworth Call records the presence of a western species of *Unio* in a small isolated eastern lake, which was located down between high hills, fed by a mountain brook, and absolutely foreign to any stream through which the species might have been introduced.

But the most conclusive objection to accepting this evidence as a proof of river-capture is found in the actual distribution of the very shells upon which the argument is based. The genus *Pleurobema* is found in both the Tennessee and Coosa-Alabama basins. In no case are the species in the two basins identical, but only similar. The basis of the argument, then, is similarity of forms. But if mere similarity of forms proves former river connection, certainly identity of form should prove it with double force. Accordingly we should not expect to find the same species of *Pleurobema* in any two rivers of this section whose location is such as to render practically impossible a former connection with each other. An examination of Mr. Simpson's important monograph on the pearly fresh-water mussels shows that *Pleurobema similans* Lea, is found in Black Warrior and Cahawba rivers, Alabama, and Pine Barren Creek, Escambia County, Florida. So far as can be judged from available maps, previous fresh-water communication between the former and the latter is extremely improbable. *Pleurobema strodeana* Wright, is recorded from Escambia River, Florida, and Flint River, Georgia. Any former connection in this case seems impossible. *Pleurobema harperi* Wright, is recorded from Altamaha and Flint rivers, Georgia, and Suwanee River, Florida. Here, again, connection between either of the former and the latter seems out of the question. Other cases might be added—indeinitely, if we continue with other genera than

Pleurobema. If we find it impossible to hold river-capture responsible for the distribution of identical species in all these cases, then mere similarity of forms in the Tennessee and Coosa-Alabama basins can not be regarded as proof of river-capture near Chattanooga.

If we carry this line of argument to its logical conclusion, the objections to it become even more apparent. One group of *Unios* is recorded as occurring everywhere in the streams draining into the Atlantic from Labrador to Georgia. If the occurrence of the *Pleurobema* in the Tennessee and Coosa-Alabama rivers proves river-capture in that case, then the distribution just referred to must prove a great succession of river-captures from Labrador to Georgia. The same species is, in one instance, found in Europe, northern Asia, Japan, northern North America and Iceland. According to the argument advanced this means world-wide land connections and an inconceivable series of river-captures. Such violent hypotheses compel the conclusion that some other means than river-capture is most commonly operative in effecting the distribution of fresh-water shells.

It is believed that all the phenomena noted are easily explicable independently of the theory of capture, and, in this connection, it is well to note that the presence of a longitudinal, open valley across the low divide between the two basins is peculiarly favorable for the operation of some of the means of dispersal referred to above. The northward and southward migrations of birds along certain valleys is known, and where a low divide in a prominent valley alone separates the waters of two river systems it is to be expected that more or less mingling of forms will very likely take place.

In our consideration of this line of evidence it is of interest to recall Mr. Simpson's statements regarding the dispersal of these shells, which appear in his paper on the 'Distribution of North American Unionidæ,'* published

seven years prior to his Tennessee paper. In a footnote (p. 354) he observes: "In many cases the Unionidæ seem to have had no difficulty in migrating across the country from river to river; an example of this being the Mississippi Valley species which inhabit all the rivers of Texas, and some of those of eastern Mexico; while on the other hand, species of South America extend up into Central America. The embryos, in some cases, may be carried by aquatic birds in the manner elsewhere mentioned in this paper; in others, they probably migrate across overflowed regions near the sea, in time of floods." Further on (p. 358), in accounting for the presence of *Unio luteolus* in both the Missouri and Columbia rivers, Mr. Simpson says: "I have traced it up the Missouri River to near its source, and when it is taken into consideration that the Marias, a tributary of this stream, heads within a few miles of Flathead Lake on Clarke's River, a branch of the Columbia, and that the embryos of *Unios* are provided with hooks by which they can attach themselves to the feet or feathers of aquatic birds, it is very easy to see how this species might have been carried from the waters of one drainage system to those of another."

It is believed, then, that the well-authenticated means of dispersal of mollusca, and more especially the facts of molluscan distribution, are such as to render it impossible to regard the distribution of fresh-water faunas as a conclusive evidence of drainage modifications. We must place this line of evidence in the second of the two classes outlined above—it being the result of river-capture in some cases, but being also produced as a result of other agencies. Whether the Tennessee River has suffered capture or not is a question which can not be settled on the basis of this class of evidence. Other sources must be appealed to. And while the Tennessee problem is a question in itself, it may not be amiss, especially in view of the wide attention attracted by the application of this line of evidence to that problem, to say that I have elsewhere pointed out certain objections to the theory of recent capture, and called attention to a variety of evidence now available

* 'On the Relationships and Distribution of the North American Unionidæ, with Notes on the West Coast Species,' *American Naturalist*, XXVII., 353-358, 1893.

which seems to indicate that the Tennessee has persisted in its present course for a long period of time.*

If the distribution of fresh-water faunas can not be regarded as a proof of river-capture, it is pertinent to ask, of what value is this class of evidence?

It seems to me that this will largely depend upon local conditions which must be taken into account in each individual problem. If there is a marked similarity or identity of forms in the captured stream and the stream representing the supposed former, lower course, and no such relation is found in any other two streams of the region, the evidence would be very suggestive. If the special forms thus distributed are so constructed anatomically as to be poorly adapted to dispersion by birds, insects, etc., the evidence would become much stronger. But if the divide between the two basins is low and indistinct and occurs in a broad, open valley along which aquatic birds are known to migrate habitually, and the shells in question are adapted to the various means of dispersal, then the opportunities for transference of forms between the two basins would be so excellent that the faunal evidence would be worthless as a proof of river capture. On the other hand, where no commingling of forms occurs, it might appear that no recent capture could have taken place and the evidence thus become of negative value. But even here we must take into consideration the restricted distribution of some forms along the same stream, due to the character of shores and stream bed, the intervention of falls or rapids and other features. Even where capture has taken place, the forms may not be transferred to the lower, new course of the stream, since they may not be found in the lower courses of streams long established in their present relations.

In conclusion, it is believed that the dispersion of fresh-water faunas is effected by so many different agencies, and the features of distribution are dependent on so many different factors, that such distribution

can have but very limited value as an evidence of drainage modifications. In the cases where this evidence has already been offered as a proof of river-capture, it is believed that the conditions are such as to render its use invalid. It seems necessary to subject such evidence to unusually critical examination before *offering* it in support of any theory of drainage modifications, or *accepting* it as proof of the correctness of any such theory.

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CURRENT NOTES ON METEOROLOGY.

LONG-RANGE WEATHER FORECASTS.

THE Weather Bureau has wisely published a *Bulletin* (No. 35) on the subject of 'Long-Range Weather Forecasts,' prepared by Professor E. B. Garriott, in order to counteract, so far as is possible, the misleading predictions for a month or a season in advance which are constantly finding their way into our newspapers. Indeed, such spurious long-range predictions are actually sold to the papers and to the public, and are most injurious in their effects. Long-range predictions are of various kinds, ranging from those based upon supposed planetary influences to such well-known statements, found in farmers' almanacs, as 'About—this—time—expect—showers,' these five words being so printed that they apply to a week or ten days of time. There are also other classes, based upon a careful study of sunspot periods, lunar periods, etc., some of which, as in the case of the recent investigations of Sir Norman Lockyer and Dr. W. J. S. Lockyer, seem to promise something in the way of more definite results. As to lunar influences, although much time has been spent on this matter, and faint lunar tides in the atmosphere have been made out near the equator, in the present state of our knowledge, as Angot put it two or three years ago, 'it can not be affirmed that the moon does exert any influence upon the weather, but at the same time it should not be denied that this influence may possibly exist.' As to seasonal predictions based upon the behavior and condition of animals, it is clear that the physical

* The full discussion of the Tennessee problem will appear in a forthcoming issue of the *Journal of Geology*.